Improvement of conversion efficiency of dye-sensitized solar cells by surface modification using microplasma

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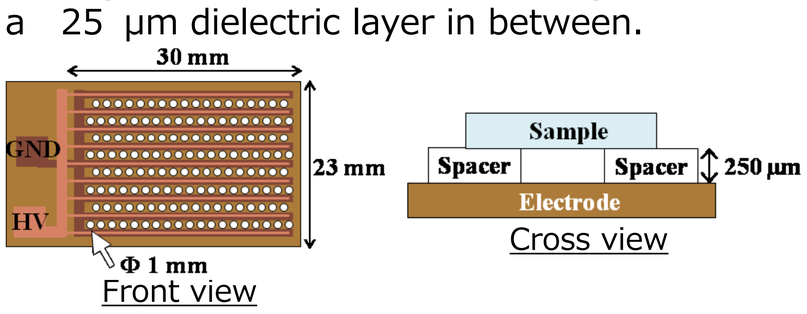
The surface modification for film dye sensitized solar cells (DSSCs) was carried out using atmospheric pressure microplasma. The DSSCs consisted of Pt counter electrode, electrolytic solution, dye, titanium oxide (TiO_2) layer and indium tin oxide (ITO) film electrode. The surfaces of TiO_2 layer and ITO film were treated by argon microplasma generated by the film microplasma electrode. After microplasma treatment, the photo conversion efficiency of DSSCs was improved by 9-27% in comparison with the untreated samples. It was observed using the contact angle measurement that the hydrophilic property of ITO film was improved. The amount of dye adsorption of TiO_2 layer was increased.

1. Introduction

DSSCs have been gathered much attention due to advantages such as cost effectiveness. Although many attempts have been carried out in recent years, the photo conversion efficiencies of ITO and TiO_2 based DSSCs remained almost the same. Aiming to improve film DSSCs, this study deals with surface modification of film DSSCs using atmospheric pressure microplasma generated using the film microplasma electrode.

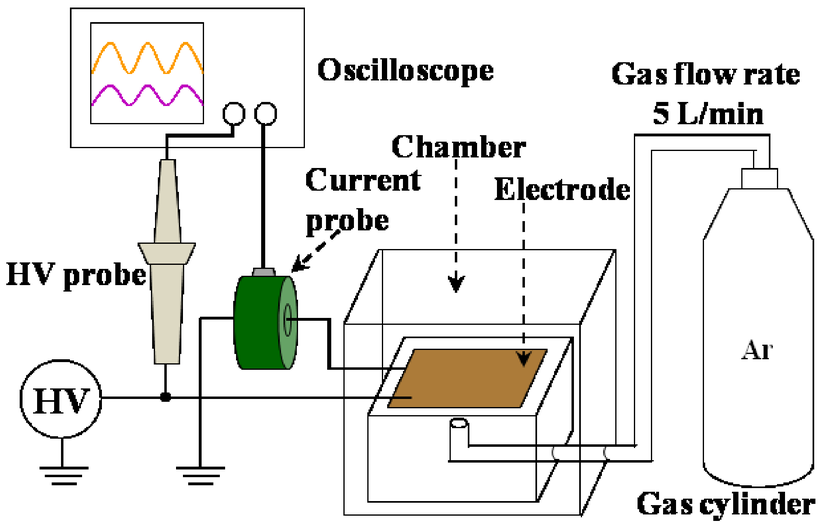
2. Experimental Methods

The electrode system was used for surface modification of ITO film or TiO_2 layer and it consists in one high voltage electrode and one grounded electrode faced together with a 25 μm dielectric layer in between.



Microplasma electrode

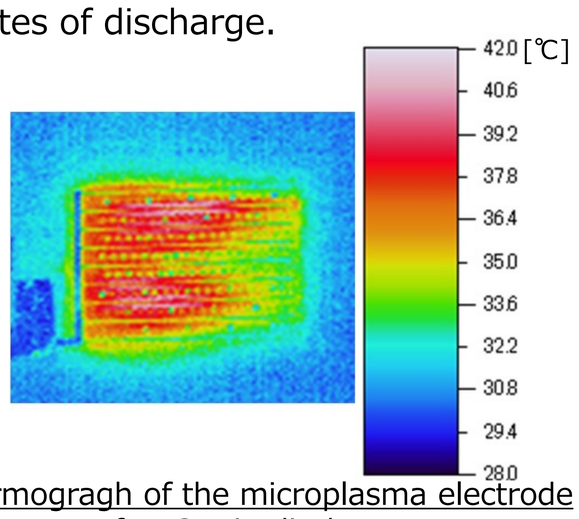
Film electrode with sample was placed in a plastic chamber. The volume of the chamber was 3.4 L. After argon gas was supplied to the chamber for 30 seconds, AC voltage (500 V, 27 kHz) was applied to the microplasma electrode and plasma was generated.



Experimental set up for surface modification

The argon gas flowed to the sample through Φ 1 mm holes of the microplasma electrode. Active species, radicals and ions were generated and flowed by argon gas and affected the surface of treated objects.

The surface maximum temperature of microplasma electrode was 41.65 ℃ after 3 minutes of discharge.



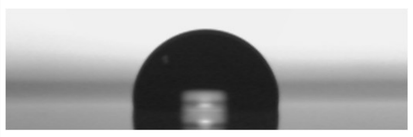
Thermogragh of the microplasma electrode after 3 min discharge

3. Results

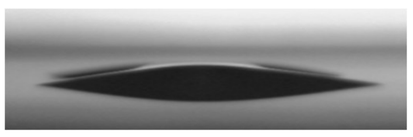
3. 1 Contact Angle Measurement

Experimental condition (3.1)

Target	ITO film
Process gas	Argon
Irradiation distance	125 ~ 1250 μm
Gas flow rate	5.0 L/min
Chamber volume	3.4 L
Treatment time	0 ~ 180 s
Applied voltage	500 V

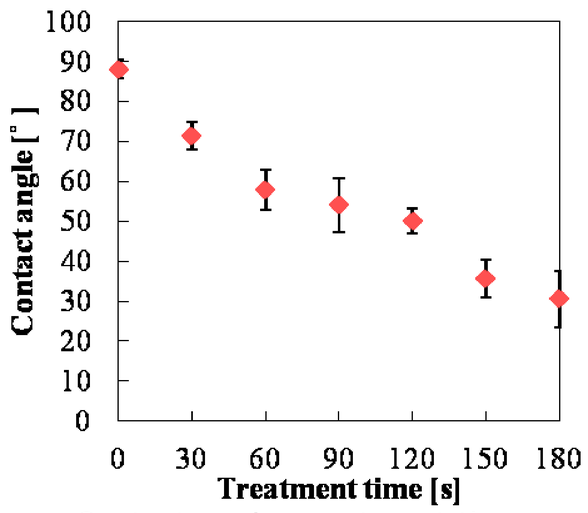


The water droplet on the untreated ITO film

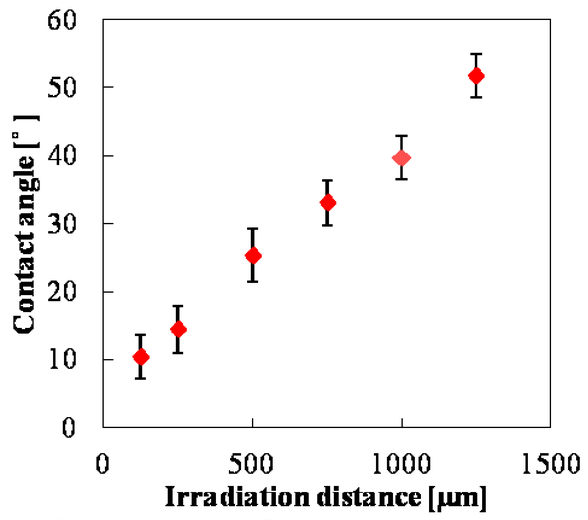


The water droplet on the ITO film treated for 3 min irradiation distance: 250 μm

With the increase of treatment time the contact angle decreases. By increasing the distance between microplasma electrode and the target the contact angle increases. After 3 minutes of treatment at a distance between the microplasma electrode and the sample of 250 μm, a significant modification of the surface was observed.



Contact angle–Treatment time



Contact angle-Irradiation distance

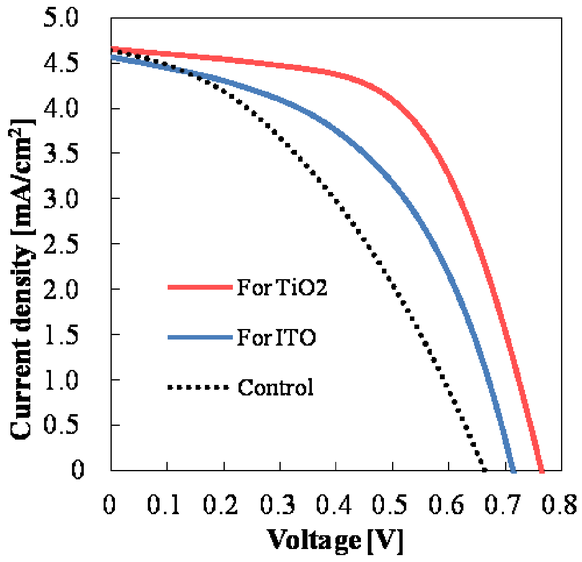
3. 2 Photovoltaic Measurement

Experimental condition (3.2, 3.3)

Target	TiO_2 layer
Calcining temperature	120 ℃
Calcining time	15 min

Process gas	Argon
Irradiation distance	250 μm
Gas flow rate	5.0 L/min
Chamber volume	3.4 L
Treatment time	3 min
Applied voltage	500 V

The solar conversion efficiency (η_C) of the control sample was 1.66%. After treatment of the ITO film and TiO_2 layer, η_C was increased to 1.81% and 2.11%, respectively.



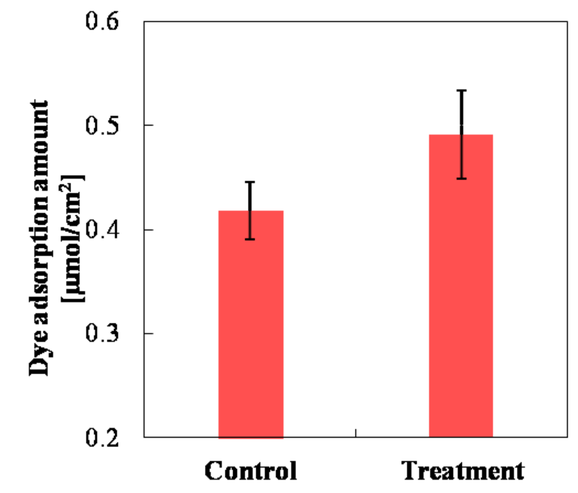
I-V characteristics of median samples

Average parameters of film DSSCs between control sample and treatment sample

Condition	J_{SC} [mA/cm²]	V_{OC} [V]	FF	η_C [%]
Control	4.54	0.72	0.50	1.66
ITO film	4.78	0.72	0.53	1.81
TiO_2 layer	4.68	0.75	0.60	2.11

3. 3 Dye Adsorption Amount Measurement

Experimental condition is shown in 3.2. The amount of dye adsorption of treated samples was increased by 18%. The number of samples was 4 for each process. The dye adsorption of TiO_2 layer consists of ester bonds which locate between hydro oxide groups on TiO_2 surface and carboxyl groups of N719 dye. The hydrophilicity of TiO_2 layer could be considered that was improved due to the generation of hydrophilic group.



Comparison of dye adsorption amount between control samples and treated samples.

4. Conclusions

- After microplasma treatment of the surface of ITO film, the photo conversion efficiency was improved by 9% in comparison with the untreated samples. After treatment of the TiO_2 layer, the efficiency was improved by 27%.
- Plasma irradiation of the ITO film caused the increase of the hydrophilic property.
- Increase of amount of dye adsorption was caused by microplasma treatment of TiO_2 layer.